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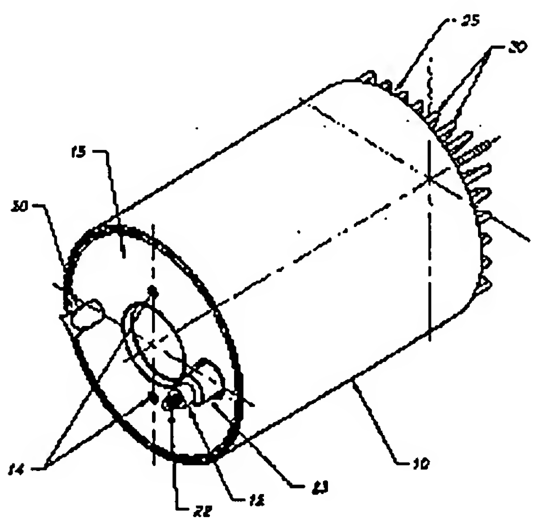
(54) HIGH PRESSURE ARC LAMP WITH INTERNAL REFLECTOR AND APPLICATIONS THEREFOR

(54) LAMPE A ARC HAUTE PRESSION EQUIPEE D'UN REFLECTEUR INTERNE ET APPLICATIONS EN DECOULANT

Representative Drawing:



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ABSTRACT:

A high pressure, short arc lamp with an internal reflector and capable of much higher operating pressures and temperatures than existing compact, short arc lamps is provided using an all metal enclosure. The arc lamp can safely contain gas fill pressures of 200 psig and provides greatly improved heat transfer capabilities as compared with prior art arc lamps to permit operation at high power levels. In a preferred embodiment, the arc lamp is filled with composites and resins and tooth whitening procedures.

CLAIMS: Show all claims

*** Note: Data on abstracts and claims is shown in the official language in which it was submitted.

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High Pressure Arc Lamp With Internal Reflector and Applications Therefor

Background of the Invention

This invention relates to an arc lamp containing an inert gas pressurized to several or more atmospheres. More particularly, this invention relates to a high pressure, short arc discharge lamp with an internal reflector and compact design to provide a high power point source of light. The lamp utilizes an inert gas such as argon or xenon gas and can operate at tens to thousands of watts. The invention further relates to applications for such a lamp, including curing of photocurable materials, and tooth whitening procedures.

Arc lamps, particularly short arc xenon lamps, are known in the art for various applications, such as infrared and visual searchlights, fiber optic illumination, spectroscopy, stadium lighting, stage and screen lighting, automobile headlights, and microscopy. The spectral distribution of xenon lamps is similar to that of natural daylight.

In addition, short arc xenon lamps with internal reflectors are known in the art. The use of internal reflectors allows for compact designs. For example, U.S. Patent No. 4,633,128 to Roberts et al. generally describes the typical construction of a short arc lamp with an internal reflector. Such lamps include a sealed, concave chamber with a gas such as xenon pressurized to several atmospheres at ambient conditions. An anode and a cathode are mounted along the central axis of the chamber and define the arc gap. An integral concave reflector serves to collimate light generated at the arc gap and a window, typically made of sapphire, permits external transmission of the collimated light.

In order to electrically isolate the two electrodes, existing short arc lamps use a ceramic body, typically made from a ceramic alumina material, from which the concave inner surface is formed. Metal bands are used at the base and window ends of the ceramic body to provide an electrical conductor for the electrodes and mount the window assembly, respectively. Roberts et al. illustrates this type of configuration for an arc lamp. The internal surface of the ceramic, which may be parabolic, elliptical, or aspherical in shape, is provided with a deposited reflective metal coating. As is recognized by Roberts et al., problems arise when these prior art arc lamps are used at high power levels. Temperatures within the lamp can exceed 2000° C, thus causing substantial temperature gradients through the lamp body. This can cause cracking of the reflector surface or ceramic body when the lamp is operated at

high wattages, i.e., exceeding 800 watts. Such cracking can cause discontinuations or discolorations in the reflective surface of the lamp, thereby diminishing its effectiveness. Moreover, cracks can lead to an explosion of the lamp.

U.S. Patent No. 3,715,613 discusses the limitations of arc lamps using ceramic bodies when operated at high pressures. These include the limited tensile strength of ceramic, the limited strength of the brazed joints between the ceramic body and metal members, and the problems associated with cooling the lamp due to the relatively low thermal conductivity of the ceramic.

The use of light, and in particular light in the blue spectrum, is beneficial in tooth whitening procedures because light in this wavelength tends to be more readily absorbed by yellow/brown colored stain molecules but mostly reflected by the red colored tooth pulp in vital teeth. One such tooth whitening procedure utilizes a whitening agent, such as a peroxide compound, in combination with laser light from an argon laser to generate free oxygen radicals to accelerate the whitening process. Such procedures, however, can require a lengthy office visit due to the amount of time each tooth must be exposed to laser light in order to effectuate the whitening process. This is because the argon lasers used in these procedures typically have output powers in the range of 250 mW - 500mW.

The spectral output of an arc lamp may be adjusted by altering the fill pressure and thus the gas density within the sealed chamber of such a lamp. In particular, depending on the gas or combination of gases used, higher fill pressures for arc lamps are desirable because varying the fill pressure causes slight but desirable shifts in the spectral output of the lamp. Such shifts are significant in that they provide for additional power in desired wavelengths and thus increase the efficiency of the lamp. For example, an increase in pressure of argon in an arc lamp results in a shift in spectral output that increases the amount of blue light generated. Blue light is desirable because it is useful both for curing photocurable resins and composites and in tooth whitening procedures. Thus, it is possible to increase the efficiency of an arc lamp by increasing the fill pressure to obtain the same output level in the blue spectrum with less input power.

However, prior art arc lamps are unable to accommodate fill pressures much above 50 psig due to their construction using a ceramic body. And the use of argon in a short arc lamp at 50 psig is not practical because at this pressure, the power output in the visible

spectrum is insufficient to create an efficient system for curing and whitening applications. At 50 psig, xenon gas is more efficient for providing visible output. Thus, prior art arc lamps utilize xenon gas due to the limitations of the design of these lamps. Applicant has found, however, that due to the shifts in spectral output achieved, the use of argon gas at a fill pressure of 200 psig significantly increases the efficiency of an argon arc lamp system beyond that of a short arc xenon lamp with a 50 psig fill in terms of visible output. Moreover, argon gas is significantly less costly than xenon gas. Thus, there is a need for a compact arc lamp design that can safely withstand fill pressures of at least 200 psig.

Prior art arc lamps have attempted to address this problem with complicated multi-part designs that attempt to place ceramic insulators in compression rather than tension. For example, U.S. Patent No. 4,179,037 discloses a ceramic ring separating a cathode ring and an anode ring. Kovar sealing rings separate the ceramic ring from the anode and cathode rings. This design, however, is complicated due to the two piece housing and ceramic sealing ring structure, and thus costly to manufacture. In addition, although the ceramic ring is stronger in compression than tension, it is still the weak point of the structure and thus limits the pressure of the gas that may be used within the arc lamp.

U.S. Patent No. 3,715,613 discloses a high pressure arc lamp with an all metal enclosure which comprises the cathode and a ceramic insert to isolate the anode from the cathode. The ceramic insert is brazed to the interior of a portion of the metal enclosure. The design is intended to place the ceramic in compression as opposed to tension as ceramic is much stronger in compression as opposed to tension. This design, however, is complicated and difficult to manufacture because the portion of the metal housing that encases the ceramic insert must have a coefficient of thermal expansion that closely matches that of the ceramic. Thus, the housing is made from two separate materials that are joined together. In addition, like prior art designs using a ceramic body for the lamp, the ceramic insert is in the heat transfer path and thus presents problems in dissipating heat due to its relatively low heat transfer properties. Thus, specially designed heat transfer members are required to transfer heat from the ceramic to the metal enclosure. In addition, this design is not readily refurbishable.

There is thus a need for a compact, high pressure arc lamp with an internal reflector that is economical and easy to manufacture and does not suffer from the drawbacks of prior art arc lamps.

For both composite and resin curing as well as tooth whitening procedures, higher power light sources are desirable to both reduce the time for completing the procedure and improve the results thereof. For example, for both these applications, the energy requirements are determined in accordance with a total amount of energy to be imparted to a given tooth. Typically, 20 joules of total energy per tooth is the maximum energy provided for both curing and tooth whitening applications. This figure is used to ensure that the pulp in vital teeth is not damaged. Existing curing lamps and lasers used for curing and whitening procedures generally operate at power levels of less than 1 watt. Thus, it takes in the range of 20-60 seconds to impart the required amount of energy to a tooth. Due to the problem of heat dissipation, however, power levels in arc lamps using a ceramic body are limited because of the relatively poor thermal properties of ceramic and the greatly reduced strength of ceramic at elevated temperatures.

As discussed above, it is desirable to use elevated fill pressures to achieve these power outputs with greater efficiency. In particular, an arc lamp that can operate at fill pressures of 200 psig is particularly desirable because of the significant increase in efficiency made possible by the resulting shift in spectral output.

Improved results are obtained during curing because photocurable composites and resins typically exhibit improved properties the faster they are cured. Similarly, with regard to whitening procedures using peroxide compounds, the bleaching efficiency of the peroxide is improved because as more energy is applied, more of the peroxide is broken down into free oxygen radicals. The longer the peroxide is resident on a tooth, the greater the amount of molecular oxygen produced, which does not have nearly the same bleaching effect as free oxygen radicals.

Summary of the Invention

In accordance with the present invention, a high pressure arc lamp with an internal reflector is disclosed. The housing of the lamp is formed entirely from metal and is maintained at the same potential. A concave metal, glass, or ceramic reflector defining a curved reflecting wall is fitted within the housing symmetrical about a central axis of the

lamp. A circular window is mounted within the metal wall opposite the reflector and symmetrical about the axis of the lamp to pass focused light. The cathode is suspended within the housing and enters through this same metal wall opposite the reflector. The cathode is isolated from the anode by a dielectric material disposed between the cathode and the metal wall. With the design of the present invention, internal gas fill pressures of 200 psig (at ambient conditions) are possible in a compact design. In addition, because of the all metal housing, the lamp may be operated at powers of up to 3000 W and more as the heat generated by the lamp is efficiently transferred through the end of the lamp opposite the window.

The present invention also encompasses a method of curing photocurable materials using a high pressure arc lamp with an all-metal housing and internal reflector. The method includes providing a light guide to direct the output of a lamp of the present invention to a material to be cured and energizing the lamp for a sufficient amount of time to cure the material. The present invention further encompasses a method of whitening teeth using a high pressure arc lamp with an all-metal housing and internal reflector. The method includes treating a tooth to be whitened with photoactivated bleaching composition, and providing a light guide to direct the output of a lamp of the present invention to the tooth and energizing the lamp for a sufficient amount of time to cure the material.

The present invention also includes a method of curing photocurable materials using a compact argon arc lamp with an internal reflector. The method includes providing a light guide to direct the output of a lamp of the present invention to a material to be cured and energizing the lamp for a sufficient amount of time to cure the material. The present invention further includes a method of whitening teeth using a compact argon arc lamp with an internal reflector. The method includes treating a tooth to be whitened with photoactivated bleaching composition, and providing a light guide to direct the output of a lamp of the present invention to the tooth and energizing the lamp for a sufficient amount of time to cure the material.

An advantage of the present invention is that a compact, short arc lamp with an internal reflector is provided that may be operated at high pressures and power levels. With the design of the present invention, input powers of over 1500 watts for continuous operation are possible.

An additional advantage of the present invention is that a high pressure arc lamp is provided in an envelope comparable to that of prior art arc lamp systems, thereby allowing for shifting of the spectral output of the lamp to improve its efficiency.

A further advantage of the present invention is that a compact arc lamp with an internal reflector is provided that is capable of safely operating at significantly greater pressure levels than prior art arc lamps.

A further advantage of the present invention is that a compact arc lamp with an internal reflector is provided that is capable of operating at significantly greater power levels than prior art arc lamps.

An additional advantage of the present invention is that it provides improved methods of both curing resins and composites and tooth whitening using a high pressure arc lamp with an internal reflector.

An additional advantage of the present invention is that it provides improved methods of both curing resins and composites and tooth whitening using an argon arc lamp with an internal reflector.

An additional advantage of the present invention is that it provides for a an arc lamp design that is relatively simple to manufacture and can be refurbished by the replacement of parts that have degraded.

Brief Description of the Drawings

The foregoing summary, as well as the following detailed description of a preferred embodiment, is better understood when read in conjunction with the drawings appended hereto. For purposes of illustrating the invention, there is shown in the drawings a presently preferred embodiment, it being understood, however, that the invention is not limited to the specific instrumentalities and components disclosed herein.

Fig. 1 is an isometric view of an embodiment of the high pressure arc lamp of the present invention.

Fig. 2 is a cross-sectional view of an embodiment of the high pressure arc lamp of the present invention, taken along the centerline of the lamp.

Fig. 3 is a detailed view of the cathode assembly of one embodiment of the arc lamp of the present invention.

Fig. 4 is a detailed view of the anode assembly of one embodiment of the arc lamp of the present invention.

Fig. 5 is a cross-sectional view of a water-cooled embodiment of the high pressure arc lamp of the present invention, taken along the centerline of the lamp.

Fig. 6 is detailed view of the window assembly of one embodiment of the present invention.

Fig. 7 is a cross-sectional view of an embodiment of the high pressure arc lamp of the present invention including an adapter for mating with a fiber optic connector.

Fig. 8 is the diagram for the spectral output of a filter that may be used in conjunction with the arc lamp of the present invention for curing and tooth whitening applications.

Detailed Description of the Invention

The present invention comprises a high pressure, arc lamp with an all metal enclosure and an internal reflector. The lamp housing of the lamp is formed entirely from metal and is maintained at the same potential. A concave metal reflector defining a curved reflecting wall is fitted within the housing symmetrical about a central axis of the lamp. A circular window is mounted within the metal wall opposite the reflector and symmetrical about the axis of the lamp to pass focused light. The cathode is suspended within the housing and enters through this same metal wall opposite the reflector. The cathode is isolated from the anode by a dielectric material disposed between the cathode and the metal wall. With the design of the present invention, a gas fill pressure of 200 psig is possible in a compact design. In addition, because of the all metal housing, the lamp may be operated at powers of up to 3000 W and more as the heat generated by the lamp may be efficiently transferred through end of the lamp opposite the window.

The metal chosen for the housing should be high in strength, have high heat transfer capabilities and be resistant to corrosion. In a preferred embodiment, stainless steel is used. The use of an all metal enclosure allows for much higher pressures and operating temperatures than is possible with prior art lamps that utilize ceramic bodies. The use of a metal enclosure also makes the lamp more durable and refurbishable and allows for much more efficient air and/or water cooling as compared with ceramic bodies.

Fig. 1 is an isometric view of a preferred embodiment of a lamp housing of the present invention. The housing 10 is in the shape of a hollow cylinder and is made from stainless steel with a wall thickness of about 0.06 in. and outside diameter of 3.0 inches. Each end of the cylinder is sealed with a cylindrical steel plate 0.25 in. thick that is welded to housing 10. Weld lips 39 are used to weld each of the end plates to the cylindrical housing. In the front end plate 15, a round hole, symmetrical with the longitudinal axis of the housing is cut through the plate in order to mount a window to permit passage of light. The window 17 is made from sapphire about 1.0 inches in diameter and 0.090 inches thick. In addition, a hole offset from the axis of the lamp is provided to mount a fill spout 20 for filling the housing with an inert gas, such as argon or xenon. The fill spout is a length of standard 0.25 inch copper tubing brazed in a through hole in plate 15, and is sealed off after filling. Cathode 22 is mounted to a dielectric ceramic insulator 23 which in turn is mounted to plate 15. A u-shaped connector 12 is provided on the end of cathode 22 to provide a mounting surface an electrical connector. The cathode 22 is electrically isolated from the plate 15, which is at the same potential as the anode, by the ceramic insulator 23. Sealing ring 21 is used to mount the ceramic insulator 23 to the plate 15. Insulator 23 is a ceramic cylinder with a through hole passing through its axis for the cathode 22. The mounting arrangement for the cathode assembly is described in more detail in connection with Fig. 3. Mounting holes 14 are provided in the plate 15 for attaching a fiber optic connector adapter and a ground potential wire.

At the opposite end, plate 25 is welded to housing 10 and is also a thickness of 0.25 in. A through hole is provided in plate 25 symmetrical with the axis of the lamp to permit mounting of the anode. Cooling fins 30 may be connected to the exterior of the plate to help dissipate heat energy generated by the lamp in operation. Mounting holes may be provided in plate 25 to permit the cooling fin assembly to be bolted to the plate. In addition, a thermal pad or paste may be used to ensure good thermal contact between the plate 25 and cooling fins 30. A small fan may be used to circulate air over the fins if required due to the duty cycle of the lamp.

The welded construction of the arc lamp of the present invention allows for the plates to be easily removed so that the lamp can be refurbished. For example, the reflector,

which will degrade as a result of operating the lamp, can be replaced and the lamp filled with fresh gas.

Fig. 2 is a cross-sectional view of the interior of a lamp of the present invention, showing many of the same features as Fig. 1. At the base portion of the lamp 25, plug 35 is welded in a central through hole of plate 25 with its exterior surface flush with the exterior surface of plate 25. Plug 35 comprises a base portion and a portion that extends into housing 10. The anode portion of the arc lamp of the present invention is shown in greater detail in Fig. 4, discussed below.

The anode 35 protrudes through a hole in the base of ellipsoidal reflector 40. Reflector 40 is an electroformed optical component comprising a nickel substrate and an electrodeposited coating of enhanced aluminum. Other coatings may be used, such as rhodium. Rhodium is a precious metal with greater than 70% reflectivity in the near ultraviolet through infrared ranges. As will be recognized by those of skill in the art, the coating is chosen dependent on the particular application for the lamp and desired wavelength of transmitted light. For example, for photocuring resins and composites and tooth whitening applications, it is desirable to use a dichroic coating which reflects visible light but does not reflect infrared light. Reflectors with various surface coatings are available from Opti-Forms, Inc. of Temecula, CA.

As indicated, in a preferred embodiment of the present invention, a 3.0 inch diameter housing 10 is used, although the all metal design permits the arc lamp of the present invention to be easily manufactured in larger or smaller sizes. An advantage of the use of a 3.0 inch diameter housing as compared with 2.0 inch diameter housings that are standard in the art is that the increased gas volume obtained with the larger diameter design dilutes the impurities released into the gas by the electrodes. That is, given the same size electrode, the density of impurities in the gas is less the greater the gas volume. In this manner, the life of the reflector is increased because less of the impurities are deposited on the reflector surface.

As shown in Fig. 2, reflector 40 is held in place within the cylinder 10 by mounting the forward facing edge of the reflector against a step 41 provided in the inner radius of housing 10. The width of the step is formed to approximately the same dimension as the thickness of the reflector at its edge. In order to keep the reflector in place during operation of the lamp, the reflector 40 may be held in place through the use of ring 42 toward

its base, as shown in Fig. 2. Ring 42 is made from 0.060 inch thick stainless steel and is welded or brazed to the interior surface of housing 10. The ring is provided with 4 through holes approximately 0.25 inches in diameter to permit the flow of gas through the reflector. Ring 42 may also be brazed to the exterior surface of reflector 40, but need not be. Those of ordinary skill in the art will recognize that other means of holding the reflector in place may be used. For example, a spring may be provided with one end mounted to the base of reflector 40 and the other to the anode 35. In this manner, as the temperature and pressure within the lamp increase during operation, thereby causing expansion of the housing, the spring would act to hold the reflector in place against the lip in the wall 10.

Alternatively, the reflector can be used as the pressure bearing surface rather than the cylindrical housing 10 and plate 25. This would require brazing the reflector 40 at its base to the anode 35 and at its edge to the lip of the housing 10. In addition, it is advisable to use heat transfer pads at the brazes to ensure good thermal contact between the reflector 40, housing 10, and anode 35. The advantage of this design is that due to its curved surface, the reflector 40 may utilize thin wall construction and still be able to withstand operating pressures. In contrast, using a flat end plate 25 requires a greater thickness of material to withstand operating pressures. Thus, a reduced weight design can be achieved by making the reflector 40 a pressure bearing component of the lamp.

A metal strip 50, referred to as a "getter," may be secured within the housing as shown in Fig. 2. The strip 50 is approximately 8.0 mm wide and 0.30 mm thick and is bent to form an accordion-like cross-section as shown in Fig. 2. The getter is fabricated from a base strip of nickel plated iron and a layer of ST 101 alloy which consists of 84 % zirconium and 16 % aluminum by weight. Getters are used to absorb impurities formed within the cavity during operation of the lamp generated by, e.g., outgassing of impurities contained within the lamp components. The getter is spot welded at each end to the interior of the housing 10. A suitable getter is the ST 101/CTS/NI/8x6 D60 getter made by Saes Getters S.p.A., an Italian company.

An advantage of the disclosed design is that the ceramic insulator 23 is subject only to compressive loads, unlike the ceramic bodies of prior art designs that are in tension. In addition, there is no ceramic in the heat transfer path from the anode. Rather, the design

of the present invention provides for an all-metal heat transfer path in a simple design that significantly increases the power level at which the lamp can operate.

The present invention also includes a novel design for mounting the cathode to the lamp. As shown in Fig. 3, the cathode 22 is mounted within ceramic plug 23 in order to insulate it from plate 15, which is at the same potential as the anode. The cathode may be made from any suitable metal as will be recognized by those of skill in the art. In a preferred embodiment, the cathode 23 is comprised of a nickel rod 0.09 inches in diameter and is bent to the shape illustrated in Fig. 2. The circumference of the rod 23 is brazed to the interior surface of a through hole provided in the ceramic cylinder 23, which is made from a ceramic alumina material. A tungsten electrode 29, terminating in a point as shown in Fig. 2, is brazed at the end of the cathode 22. As is known to those of ordinary skill in the art, the power level of the lamp may be changed by adjusting the position of the electrode 29 in the cathode 22 so as to change the size of the arc gap. At the opposite end of the cathode 23 external to the lamp, a terminal 31 is provided for applying voltage to the cathode. A s shown in Fig. 3, a ring 21 with a "z" cross section is used to mount the ceramic cylinder to the plate 15. In a preferred embodiment, ring 21 is made from stainless steel but may be made from kovar or any other suitable metal. The inner circumference of the ring is brazed to the ceramic 23 and the outer circumference is brazed or welded to the plate 15. A step 24 is provided in the outer circumference of the ceramic cylinder 23 to accommodate the ring 21. Due to the "z" cross section of the ring 21, a gap 26 exists on the exterior side of the plate 15 between the plate and the ceramic cylinder 23. Similarly, on the interior side of the plate 15 a gap 27 exists between the plate and the ceramic cylinder 23. Because the ring 21 is flexible, the ceramic cylinder 23 may be moved in any direction transverse to its axis in order to adjust the position of the cathode 22 relative to the anode 35.

Fig. 4 is a detail drawing of the anode assembly of one embodiment of the present invention. Anode 35 may be welded or brazed in a through hole provided in plate 25. In the embodiment illustrated in Fig. 4, the anode 35 is welded to the plate 25 and a weld lip 39 is provided for this purpose. As shown in Fig. 4, the base portion of anode 35 includes a lip 38 around its periphery to make contact with the interior surface of plate 25. The lip allows for self-fixturing of the anode 35 in the plate 25 when the two are welded together. Tungsten electrode 45 is brazed to the end of the protruding portion of the anode 35. In a

preferred embodiment, the tungsten electrode 45 is first brazed or welded to the anode 35, and then the combination is machined to the shape shown in Fig. 4. Copper is the preferred metal for the anode 35 because of its heat conducting properties, but other metals may be used. In order to allow for gas flow around the reflector, the interior radius of reflector 40 at its base is made larger than the radius of the protruding portion of anode 35 in order to provide an annular gap 43 between the base of reflector 40 and the anode 35. In addition, the base of reflector 40 is spaced from the base portion of anode 35 to allow for thermal expansion of the reflector 40 when the arc lamp is in operation.

The design of the anode 35 in conjunction with plate 25 provides for significantly improved heat transfer as compared with prior art ceramic arc lamps. Rather than transferring heat from the anode through a ceramic material as in prior art designs, the heat is transferred directly through a highly thermally conductive material such as copper. As shown in Fig. 2, the anode 35 may be thermally coupled to cooling fins 30 to facilitate heat removal.

Fig. 5 illustrates an alternate embodiment of the present invention intended for high duty cycle operations and power levels greater than 1600 watts. The design of the present invention provides for much improved water cooling capabilities than existing designs. As shown in Fig. 5, a water (or other coolant) supply tube 36 may be made integral with anode 35 so as to provide cooling water to the rear surface of tungsten filament 45. In this embodiment, to facilitate welding of the anode 35 to the plate 25, the weld is placed in the internal side of the plate 25. In this case, a lip is provided on the external side of anode 35 to provide for self-fixturing during welding. Due to the design of the arc lamp of the present invention, a very short thermal path for heat generated by the lamp is provided to permit continuous operation at high power levels. A return tube 37 is welded or brazed to tube 36 to provide a return path for the cooling water.

Fig. 6 illustrates a detail of the sapphire window assembly. Window 17 is brazed along its periphery to kovar ring 18, which is welded or brazed to the plate 15 along its outer circumference. In the embodiment shown in Fig. 6, the kovar ring 18 is welded to the plate 15 and a weld lip 39 is provided for this purpose. As shown in Fig. 2, a lip 19 is provided in the kovar ring 18 along the interior surface to provide a surface upon which the window 17 bears. This helps to minimize the risk that the window can be forced from the

enclosure due to the internal pressure. An annular gap 13 is provided between the plate 15 and the kovar ring 18 to allow for thermal expansion of the window assembly during operation of the lamp.

Fig. 7 illustrates the arc lamp of the present invention provided with a fiber optic connector 70 mounted to the exterior of plate 15. In a preferred embodiment of the present invention, the body of the lamp, including the housing 10 and end plates 15 and 25, are maintained at ground potential. This allows for the mounting of metal components to, and easy handling of, the lamp. The coupling may thus be made from stainless steel or another metal and is provided with an internal conical portion 72 that tapers to a cylindrical portion 74, both central with the axis of the connector 70 as shown in Fig. 8. In addition, an area 75 is provided in which to place an optical filter if desired for the particular application of the lamp. The point at which the transition is made from the conical portion to the cylindrical portion is the focus point of the light provided by reflector 40 through window 17. The free end of connector 15 is designed to receive a standard fiber optic coupling. One advantage of the present invention is that any type of coupling or adapter may be mated with the lamp as it is at ground potential.

The present invention also relates to improved methods of curing photocurable resins and composites and whitening teeth using the arc lamp of the present invention. For curing applications, tungsten, halogen, and metal halide lamps are commonly used because of their relatively flat spectral distribution in the visible range. In addition, it has been found that visible light, particularly in the blue spectrum, is useful both for curing and tooth whitening applications. An optical filter is used to provide output light primarily in the blue range, i.e., approximately 470 nanometer wavelength.

In accordance with the present invention, improved methods of curing and tooth whitening may be realized by using the arc lamp of the present invention filled to 200 psig of argon in these procedures. A short arc argon lamp filled to about 200 psig exhibits a peak in spectral output at about 470 nanometers. Thus, an argon arc lamp operating at 200 psig provides for significantly improved efficiency in terms of delivering optical energy in the blue wavelength as compared with a xenon arc lamp. For example, with an input power of 1500 watts, a minimum of 5 watts may be delivered from the lamp, through a light guide to the composite to be cured.

The following conversion table shows the energy setting used with a lamp of the present invention as a function of the composite curing time recommended by the manufacturer of the composite, based on a conventional tungsten halogen curing light with an output power of 500 mW/cm² and a 0.950 cm² probe (for a total output power of 475 mW). Also shown in Table 1 are curing times for the system of the present invention, based on an assumed power of 5.0 watts at the distal end of a light guide, which is placed proximate the composite to be cured. It is likely that the actual power output is significantly higher, however, as a fill of 200 psig optimizes the output in the range of about 430-505 nanometers, so that the curing times will actually be even lower than those indicated.

Table 1

Joule Equivalents for Manufacturer Recommended Curing Times			
Recommended Composite Curing Time (for conventional curing light)	Joules for conventional curing light (based on an output power of 475 mW)	Composite Curing Time (for high pressure arc lamp)	Joule Equivalent (for high pressure arc lamp)
10 seconds	4.75	0.3 seconds	1.5 Joules
20 seconds	9.50	0.6 seconds	3.0 Joules
30 seconds	14.25	0.9 seconds	4.5 Joules
40 seconds	19.0	1.2 seconds	6.0 Joules
50 seconds	23.75	1.5 seconds	7.5 Joules
60 seconds	28.50	1.8 seconds	9.0 Joules

When the lamp of the present invention is used for both curing and whitening applications, a filter may be used to reject undesirable wavelengths of light and in a preferred embodiment has the characteristics shown in Fig. 8, which illustrates the percent transmission as a function of wavelength. As indicated in this figure, the filter substantially eliminates light with a wavelength below about 430 nanometers and above about 505 nanometers but transmits light between these two wavelengths. As discussed above, reflector 40 may be provided with a dichroic filter to prevent infrared energy from being transmitted through window 17. If a reflector without a dichroic coating is used, a separate, dichroic filter may be employed to absorb and dissipate infrared energy.

As will be apparent to those of skill in the art, the actual curing time will depend on the power levels of the optical energy delivered to the composite (in the frequency range passed by the filter), which in turn depend on the input power to the arc lamp and the fill pressure and specific gas or gases used.

The benefits of using a high powered light source in both curing and tooth whitening applications -- in terms of both reducing the time required for the procedures and improving the results obtained -- are discussed in copending patent application titled "Portable High Power Arc Lamp System and Applications Therefor," filed December 24, 1996 by John C. Cipolla, the disclosure of which is incorporated herein by reference. In addition, the use of the high pressure argon lamp of the present invention allows for delivery of higher power in desired frequency ranges and thus reduces the required power input.

In order to adapt the arc lamp of the present invention for use in curing and tooth whitening applications, a light guide made from flexible material, such as a bundle of fiber optic cables housed inside a flexible sheath, may be attached to the fiber optic connector adapter 70. This permits the delivery of the output of the lamp to desired tooth surfaces. In a preferred embodiment, a more flexible, high power, solid state light guide made from a partially polymerized polymer is used, available from Translight of Pomfriet, Connecticut. Flexibility of the light guide is important to provide the user with sufficient maneuverability of the light guide. Therefore, several feet of light guide are required to provide a sufficient length for normal work conditions.

For tooth whitening applications, the lamp of the present invention may be used in conjunction with tooth bleaching compositions such as those containing peroxide compounds. Existing methods of tooth whitening use comparatively low powered argon lasers to activate the bleaching composition. Use of the present invention, which can operate at much greater power levels, will greatly reduce the time required for such procedures and improve the results because the faster the light energy is applied to, for example, hydrogen peroxide, the greater the amount of free oxygen radicals produced as opposed to molecular oxygen, which is far less effective in bleaching teeth.

The invention has been described in greatest detail with respect to the particular embodiments and exemplary applications described above. It is understood by those of ordinary skill in the art that changes may be made to the embodiments described herein

without departing from the broad inventive concepts thereof. The invention is not limited by this embodiment and examples, but is limited only by the scope of the appended claims. For example. the lamp of the present invention may be filled with any inert gas or combination thereof. The much higher pressure capacity of the lamp as compared with prior art designs allows for many more options than previously available with regard to the ability to adjust the gas fill to maximize output power in a particular frequency band. Moreover, the higher power outputs and superior heat dissipation capabilities of the lamp of the present invention allow for its use in every field in which low pressure, ceramic arc lamps, typically filled with xenon gas, are presently the lamp of choice, including infrared and visual searchlights, fiber optic illumination, spectroscopy, stadium lighting, stage and screen lighting, automobile headlights, surgical and other medical applications, and microscopy.

I claim:

1. A compact, high pressure arc lamp system comprising:

a. a sealed metal housing comprising a hollow cylindrical portion having a front end and an aft end and circular plates welded to each said end, wherein said housing is maintained at the same electrical potential as a first electrode of said arc lamp mounted to said aft end plate;

b. a concave reflector internal to said cylindrical housing;

c. a second electrode mounted to said front end plate and electrically isolated therefrom;

d. a window mounted within said front end plate symmetrical with the longitudinal axis of said cylindrical portion of said housing;

e. an inert gas inside said housing, wherein said arc lamp is configured to operate with an internal gas pressure of at least 200 psig.

2. A method for whitening teeth comprising:

a. placing a light activated bleaching composition on a tooth to be bleached;

b. providing a short arc argon lamp with an internal reflector for directing visible light energy from said lamp through a window in said lamp;

c. coupling said visible light energy to a light transmitting member;

d. using said light transmitting member to direct said visible light on said bleaching composition for an amount of time sufficient to effect whitening of said tooth.

3. A method for curing a photocurable composite comprising:

a. placing a photocurable composite on a surface upon which it is to be cured;

b. providing a short arc argon lamp with an internal reflector for directing visible light energy from said lamp through a window in said lamp;

c. coupling said visible light energy to a light transmitting member;

d. using said light transmitting member to direct said visible light on said composite for an amount of time sufficient to cure said composite.

4. The arc lamp of claim 1 wherein said housing is made from steel.

5. The arc lamp of claim 1 wherein said reflector is made from metal.

6. The arc lamp of claim 1 wherein said reflector is made from glass.

7. The arc lamp of claim 1 wherein said reflector is made from ceramic.

8. The arc lamp of claim 1 wherein said reflector is made from rhodium.

9. The arc lamp of claim 1 wherein said second electrode comprises a cathode mounted to said front plate and suspended within said housing.

10. The arc lamp of claim 1 wherein said inert gas is argon.

11. The arc lamp of claim 1 wherein said inert gas is xenon.

12. The arc lamp of claim 1 wherein said window is sapphire.

13. The arc lamp of claim 1 wherein said first electrode comprises an anode.

14. The arc lamp of claim 13 wherein said anode is water-cooled.

15. The arc lamp of claim 1 wherein said second electrode is electrically isolated from said front end plate using a ceramic insulator.

16. The arc lamp of claim 15 wherein said ceramic isolator is mounted to said front end plate using a kovar ring so that the position of said cathode is movable relative to said anode.

17. A high pressure arc lamp comprising:

a stainless steel housing at a first electrical potential, said housing comprising a hollow cylindrical portion having a front end and an aft end, a first circular plate fixed to said front end, and a second circular plate fixed to said aft end;

a concave reflector mounted in said cylindrical housing adjacent said aft end;

an anode mounted to said second plate, wherein said anode is at the same electrical potential as said housing;

a cathode mounted to said front plate and protruding into said cylindrical housing, wherein said cathode is at a different electrical potential from said housing and said anode;

an electrical isolator mounted between said cathode and said front plate; and

an inert gas inside said housing.

18. The arc lamp of claim 13 wherein said inert gas comprises argon at a pressure of 200 psig or greater at ambient conditions.

19. A method for providing a high pressure arc lamp with an internal reflector within a sealed housing, wherein said housing is maintained at the same electrical potential, said method comprising:

providing a generally cylindrical metal enclosure with an internal concave reflector;

providing front and aft generally circular metal plates adapted for mounting to the axial ends of said generally cylindrical enclosure, said front plate comprising a window symmetrical about the axis of said enclosure;

mounting a first electrode to said aft plate and a second electrode to said front plate, said second electrode electrically isolated from said front plate;

sealably affixing said front and aft plates to opposite ends of said enclosure to form a sealed housing;

filling said housing with an inert gas.

20. The method of claim 19 wherein said enclosure and said plates are made from steel.

21. The method of claim 19 wherein said housing is filled with argon to a pressure of approximately 200 psig or greater.

22. The method of claim 19 wherein said inert gas is xenon.

23. The method of claim 19 wherein said enclosure further comprises a getter.

24. The method of claim 19 wherein said first electrode comprises an anode.

25. The method of claim 19 wherein said second electrode comprises a cathode.

26. The method of claim 19 wherein said second electrode is isolated from said front plate using a ceramic isolator.

27. The method of claim 19 wherein said anode is water-cooled.--